TOWARD THE IMPLEMENTATION OF GLOBAL STRATEGY FOR PLANT CONSERVATION TARGETS 1 TO 3 IN HAWAI'I[1]

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ABSTRACT

Hawai'i has a unique natural history, ideal for studying the mechanisms of evolution. With over 90% endemism in its native flora of 1300 species, over half are threatened with extinction. This immense challenge requires working collaboratively, effectively, and efficiently. Despite extensive conservation activity, we do not have a unified strategy, and leaders in Hawaiian conservation are discussing the creation of a Hawai'i Strategy for Plant Conservation (HSPC) based on the Global Strategy for Plant Conservation (GSPC) targets. Here we analyze the effectiveness of the conservation work taking place in Hawai'i through the lens of the GSPC Targets 1 to 3 that include: (1) the establishment of an online flora of all known plants; (2) the assessment of the conservation status of all known plant species; and (3) the development and sharing of research and methodology related to on-the-ground conservation.

Key words: Biodiversity, endemism, extinction, Global Strategy for Plant Conservation (GSPC), Hawai'i Conservation Alliance (HCA), Hawai'i Rare Plant Restoration Group (HRPRG), Hawaiian flora, IUCN, U.S. Fish and Wildlife Service (USFWS).

The framework of the international Global Strategy for Plant Conservation (GSPC) is an effective way to tie Hawai'i's conservation programs together and to measure progress toward those updated GSPC goals established at the 10th meeting of the Conference of the Parties to the Convention on Biological Diversity, 18–29 October 2010. As concluded in Nagoya, Japan, Objective I of the GSPC stated that plant diversity is well understood, documented, and recognized. Under Objective I, the GSPC uses three targets that are designed to measure the effective implementation of this objective. Target 1 is an online database for the flora; Target 2 documents the conservation status of the flora; and Target 3 refers to the dissemination and sharing of information.

Hawai'i is an ideal place to study plant evolution, because its biodiversity developed in the extreme isolation of the mid-Pacific without human interference. The Hawaiian archipelago arose from the central Pacific Ocean floor as a sort of conveyor belt of volcanic activity, emerging from the southeast, moving toward the northwest, beginning some 70 million years ago. From 230 plant colonizations, it is estimated that the archipelago evolved approximately 1345 endemic species of flowering plants (Wagner et al., 1999) and ferns (Palmer, 2003). The steep volcanic topography of the islands, with many narrow mountain drainages and inaccessible habitats, provided many small ecological niches. Taxonomic radiation into these niches led to an extremely high degree of endemism. Ninety-four percent of all dicot species are estimated to be endemic to the archipelago (Wagner et al., 1999) and a large number of those are single-island endemics, often restricted to one valley. Since human colonization only occurred an estimated 1000 to 1200 years ago, and there are no native land mammals apart from one bat species, threats to this flora were, until recently, relatively insignificant.

This contrasts dramatically to the "post-contact" competition from new introductions, be these human, animal, plant, insect pest, or disease. Over half of the remaining endemic flora is now considered at risk of extinction. With an extraordinary assemblage of more than 28,000 native plants and animals, as catalogued by the Hawaii Biological Survey database (<http://hbs.bishopmuseum.org/hbsdb.html>), the Hawaiian archipelago is one of the world's most ecologically diverse locations. A large percentage of these taxa are endemic (cf. Fig. 1). The vulnerability of these unique natural resources makes Hawai'i a microcosm for the practice and science of global bio-cultural conservation, which should be measured through an international framework like the GSPC.

This immense natural challenge requires working collaboratively, effectively, and efficiently. Despite

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Figure 1. Endemic Hawaiian plants under threat. —A. *Lobelia gloria-montis* Rock, pu‘u kukui or bog lobelia (Campanulaceae). —B. *Scaevola glabra* Hook. & Arn., ohe naupaka or camphusia (Goodeniaceae). —C. *Lysimachia daphnoides* Hillebr., lehua makanoe (Primulaceae). —D. *Polyscias bisattenuata* (Sherff) Lowry & G. M. Plunkett [≡ *Tetraplasandra bisattentuata* Sherff], ohe ohe (Araliaceae). Photos taken by Ken Wood, National Tropical Botanical Garden.

extensive conservation activity, we do not have a unified strategy, and leaders in Hawaiian conservation have discussed the creation of a Hawai'i Strategy for Plant Conservation (HSPC) based on the GSPC targets. An HSPC modeled after the GSPC will focus attention and resources on Hawai'i more effectively than the North American Botanic Garden Strategy for Plant Conservation (<http://www.bgci.org/files/Worldwide/Conservation/north_american_plant_conservation_strategy.pdf>), due to Hawai'i's unique location and natural history. The North American strategy was not written to include Hawai'i, presumably because of the dissimilarity of both the flora and the geography. The following attempts to analyze the effectiveness of the conservation work taking place in Hawai'i through the lens of GSPC Targets 1 to 3. It is important to update the national and international conservation communities on the status of the unique flora that has evolved in this biodiversity hotspot, because while the Hawaiian Islands have been visited by botanists for over 200 years, there have also been many contemporary initiatives by numerous organizations to conserve the native flora.

Target 1, an online database for the flora, has been accomplished, and Hawai'i currently has very good online documentation of its flora. Classification and naming of the Hawaiian flora began with indigenous Hawaiian culture over 1000 years ago. Western documentation based on the Linnaean system (binomial) was begun over 200 years ago, with the arrival of the Europeans. Botanists traveling with early explorers like Captain James Cook (three voyages, 1768–1779) and George Vancouver (1792) made the first known botanical collections and drawings of the Hawaiian flora. Approximately a century later, the first *Flora of the Hawaiian Island* was published by a German physician living in Honolulu (Hillebrand, 1888). Since western botanists began their investigation of the Hawaiian flora, over 100 species have gone extinct. At the same time, due to the rugged nature of the islands, dozens of new species are still being discovered. Since the flora was last systematically revised in 1990, the National Tropical Botanical Garden's (NTBG) field botanists have discovered 45 new species and a further 35 species thought to be extinct, which has expanded the existing flora by a total of 65 species (Wood, 2011).

The publication of the *Manual of Flowering Plants of Hawai'i* by Wagner et al. (1999) was a landmark effort to document the flora using modern systematic methods and remains the reference publication for all botanical research in the Hawaiian Islands, in spite of the fact that taxonomic revisions since its publication have been considerable. A parallel reference for the pteridophytes is *Hawai'i's Ferns and Fern Allies* by Palmer (2003). In collaboration with the NTBG, the Smithsonian Institution (SI) maintains an online version of the *Flora of Hawaiian Islands* (Wagner et al., 2005), which is updated with periodic supplements (<http://botany.si.edu/pacificislandbiodiversity/hawaiianflora/Hawaiian_vascular_plant_updates_1.3.pdf>).

In addition to this online flora, a number of other online resources are available. Collaboration between the Royal Botanic Gardens, Kew, and Missouri Botanical Garden (MO) created an online plant names index (<http://www.theplantlist.org>), which includes Hawaiian species. The Plant List combines multiple checklist data sets held by those institutions and other collaborators, providing the accepted Latin name for most species, with links to all synonymous names by which the taxon has been known.

Extensive collections of plant specimens are deposited in the herbarium at the Bernice P. Bishop Museum in Honolulu (BISH; <http://www2.bishopmuseum.org/HBS/checklist/query.asp?grp=Plant>). A geographical search engine is available through the MO Tropicos database (<http://www.tropicos.org/SpecimenGeoSearch.aspx>) and through the herbarium of the NTBG (<http://ntbg.org/herbarium>). The two Hawaiian herbaria, BISH and PTBG, as well as those at SI, New York Botanical Garden (NY), and MO, extensively document Hawaiian and other Pacific flora. The PTBG's type collections have been digitized and made available online on JSTOR Plants as the result of funding from The Mellon Foundation. Another project, the Consortium for Pacific Herbaria (CPH) funded by the U.S. National Science Foundation, is in progress to database and digitize Hawaiian and Pacific Island herbaria and make them available online through a single web portal hosted by the University of Hawai'i (<http://www.herbarium.hawaii.edu/cph/index.html>).

Other particular lists for the Hawaiian flora or locales corroborate the larger online databases and herbarium collections. These include a checklist of Native and Naturalized Flowering Plants of Hawaii, including the islands of Oahu, Hawai'i, Maui, Molokai, Lana'i, Kaho'olawe, Kaua'i, and Ni'ihau (<http://www.bishopmuseum.org/research/natsci/botany/dbandkeys/Main%20Islands%20Report.pdf>). Another checklist documents the northwestern Hawaiian Islands of Nihoa, Necker, French Frigate Shoals, Gardner Pinnacles, Maro Reef, Laysan, Lisianski, Pearl and Hermes Atoll, Midway, and Kure Islands (<http://www.bishopmuseum.org/research/natsci/botany/

dbandkeys/NWHI%20Islands%20Report.pdf>). Other national databases include Hawaiian plants and can be found through the Botanic Gardens Conservation International (BGCI; <http://www.bgci.org/plant_search.php/>), The Center for Plant Conservation (CPC; <http://www.centerforplantconservation.org/collection/NationalCollection.asp>), and NatureServe (2011; <http://www.natureserve.org/explorer/>). These databases incorporate data from the Hawai'i Biodiversity Mapping Program. In addition, several other databases maintained by the University of Hawai'i contain excellent photographic archives of Hawai'i's flora. The Hawaiian Native Plant Genera database (<http://www.botany.hawaii.edu/faculty/carr/natives.htm>) includes photographs of dicots, monocots, ferns, and fern allies, arranged by family and genus, and to the species level. The Plants of Hawai'i database contains both native and introduced species as well as indigenous plants (<http://www.hear.org/starr/images/?o=plants>).

Target 2 of the three GSPC targets focuses on the assessment of the conservation status of all known plant species, as far as possible. The U.S. Fish and Wildlife Service (USFWS) has the most complete data on the current status of Hawai'i's flora. Of all federal listed plants in the United States (760; <http://ecos.fws.gov/tess_public/pub/Boxscore.do>), almost half (357) are Hawaiian taxa (<http://ecos.fws.gov/tess_public/pub/stateListingAndOccurrenceIndividual.jsp?state=HI&s8fid=112761032792&s8fid=112762573902>). With current taxonomic changes, the number of federally listed Hawaiian plant taxa is 370. USFWS estimates that at least half of those taxa are limited to fewer than 1000 individuals each (Table 1).

Under the Endangered Species Act, taxa designated as Threatened (T) or Endangered (E) or candidates for listing are listed in the USFWS's Environmental Online Conservation System, either alphabetically by scientific name at <http://ecos.fws.gov/tess_public/pub/listedPlants.jsp> or alphabetically by common name at <http://ecos.fws.gov/tess_public/pub/stateListingIndividual.jsp?state=HI&status=listed>. On each species page on the USFWS web site, species profile pages for assessed species contain links to documents, including the initial proposed listings, recovery plans, critical habitat designations, and five-year reviews. These describe the conservation status of an individual species, any relevant taxonomic changes, life history research, associated habitats and species, as well as any threat to its survival. Conservation measures are recommended and implemented for species recovery. Five-year reviews have recently been completed for all Hawaiian threatened and endangered plants, with the exception of those most recently listed in 2010. Although not exhaustive, this is the best single source for information on the conservation status of Hawai'i's rare plants. It is estimated that another 78 Hawaiian plant species will be listed in the next few years (USFWS, 2012a, 2012b, 2012c), according to a new USFWS work plan available at <http://www.fws.gov/endangered/improving_ESA/listing_workplan.html>.

Table 1. U.S. Fish and Wildlife Service (USFWS) population data on the Hawaiian flora.

Abundance	# of taxa
Extinct	115
In captivity only	19
1 in the wild	12
2–20 in wild	95
21–100 in wild	123
101–1000 in wild	205
1001–5000	83
> 5000 in wild	637
Unknown	56
Total	1345

Data taken from USFWS (2011). Taxonomic note: USFWS has listed some entire species, which include a number of subspecies, and in other species only some subspecies. Subsequent to listing some taxonomic revisions have resulted in the listed species being split into a number of new species.

Another 260 Hawaiian plant species are informally designated as species of concern in the USFWS. Species of concern is an informal term not defined in the federal Endangered Species Act, but it commonly refers to species that are declining or may be in need of conservation. Species of concern may be identified as those with some or all of the following indicators:

(1) Magnitude of decline. For the species of concern, the recent rate of decline is compared relative to the historical extent of decline.

(2) Natural rarity. The plant species of concern is known only from a small number of specimens or occurs infrequently and in small numbers because of ecological or evolutionary factors.

(3) Restricted endemism. The species of concern is native to a particular and limited geographical range and is found only there.

(4) Connectivity of populations. The level of possible reproductive exchange among populations of the species of concern is estimated, given the number and distribution of known populations.

(5) Habitat. The species of concern has unique or highly specific habitat requirements that support careful monitoring of its status.

With such species of concern added to those that are officially listed, over 50% of the Hawai'i flora is considered to be at risk.

Two hundred three species with less than 50 individuals seen in the wild have been identified under the Plant Extinction Prevention Program of Hawai'i (PEP) for priority recovery efforts (<http://pepphi.org/>). The PEP list includes 49 species that are not already listed by USFWS. These additional species are also tracked in a Statewide Rare Plant Database, with regular updates from PEP field botanists on each island.

An earlier version of a statewide database, the Heritage Database, now called the Hawai'i Biodiversity Mapping Program database, contains all the historical occurrences of listed species, but has only been updated through about 2002, due to lack of resources. Additionally, the U.S. Army, Oahu, maintains its own database on those 66 Hawaiian species federally listed as T or E for which it is responsible (U.S. Army, Center for the Environmental Management of Military Lands, Colorado State University; U.S. Army, Oahu Army Natural Resource Program, U.S. Army Garrison Hawaii and Pacific Cooperative Studies Unit, 2010). Regular annual status reports on the conservation status and recovery of these species are available online at <http://manoa.hawaii.edu/hpicesu/dpw_mit.htm>.

Unfortunately, the International Union for Conservation of Nature (IUCN, 2001) Red List, which is considered the international standard for threatened and endangered species, includes only 224 endemic and two indigenous species from Hawai'i (<http://www.iucnredlist.org/>). This is in contrast to the higher number of species federally listed as T and E or on the PEP list. It is interesting that the Red List actually included several species as Vulnerable (VU) that are not listed as rare by either the state of Hawai'i or the USFWS. The Hawai'i Rare Plant Restoration Group (HRPRG), IUCN's Specialist Group for Hawai'i, has requested help in completing the IUCN listing process for additional species but has had no funding for the purpose, and the listings remain incomplete at this time. Until all T and E, PEP, candidate, and species of concern species are listed under IUCN, the global significance of the taxonomic endangerment, indeed extinctions, of the Hawaiian flora is not reflected accurately under the IUCN Red List.

A number of studies have been conducted documenting the diverse plant communities and their distribution in Hawai'i. The composition of Hawai'i's coastal plant communities has been well documented by Warshauer et al. (2009). Another project in 2007 mapped distributional ranges for four plant species, two widespread and two rare, on all the main Hawaiian Islands (Price et al., 2007), and Hawai'i was one of a number of island archipelagos reviewed for conservation priorities by Caujapé-Castells et al. (2010). This last article, however, used the IUCN listings for its statistics on rare plants in Hawai'i, so it provides an underestimate and does not reflect the actual gravity of the extinction crisis in Hawai'i's endemic flora.

The NTBG has over three decades of collection data in both its Living Collections Database and Herbarium Database (<http://www.ntbg.org/herbarium/>). In addition, the Plant Recovery Coordinator for USFWS-Honolulu maintains a database that includes candidate species not yet listed, and species of concern that are assessed to need evaluation as possible candidates for federal listing. Information is maintained on the known status of numbers of populations, individuals, threats, and latest observations. The conservation status of rare plants requires regular monitoring and updating, and more field botanists are needed to collect this information. Staffing also limits IUCN Red listing assessments for many species, so the actual endangerment of the Hawaiian flora is not accurately reflected internationally.

Target 3 of the GSPC is that information, research and associated outputs, as well as the methods necessary to implement the strategy are developed and shared. This has been implemented in many significant directions, but not in the context of the GSPC. Our recommendation is that the conservation and research community establish a mechanism, perhaps through the Hawai'i Conservation Alliance (HCA), that will effectively compile and index progress toward implementing the GSPC targets.

In general, research and conservation efforts in Hawai'i have been collaborative and various groups regularly share information with each other. Perhaps this is because everyone recognizes the magnitude of the problem and agrees that we are working toward a common goal and will need to work together if we are to achieve our goals. One way in which this collaboration has expressed itself is via the HCA, an organization of 19 leading federal and state agencies and NGOs that meet regularly to discuss conservation issues and share information. This target is being met by a wide variety of collaborative projects, database coordination, sharing of on-the-ground restoration techniques, and scientific research, but more science in support of conservation efforts is cogently needed.

The HCA has clearly noted the need for increased research that will inform effective conservation in Hawai'i (<http://hawaiiconservation.org/files/content/activities/effective_conservation/

effectiveconservationoverview.pdf>). Although science in support of conservation has been extensive over the past several decades, the sheer size of the endangered flora dictates that much more needs to be understood about Hawaiian species. More genetic analysis, pollination biology, life history and phenology, soil ecology, and related studies are needed for conservationists to effectively assess and conserve the at-risk species. Very few genera are well characterized across these disciplines, let alone the numerous species that represent Hawai'i's plant diversity. We still have much to learn in understanding how sympatric speciation, obligate outcrossing, co-evolution, indeed any species interaction, may impact any species' ability to regenerate and maintain themselves in the face of changing ecosystems. Understanding both internal and external reproductive barriers and how they evolved is also essential to long-term management of rare species.

While climate change has now been recognized as an official threat to rare species by the USFWS, the research on what this will mean in Hawai'i is just beginning. The Pacific Islands Climate Change Cooperative (PICCC; <http://piccc.net>) is a new interagency organization whose purpose is to assist those who manage native species, island ecosystems, and cultural resources in adapting their management to climate change in the Pacific Islands. PICCC coordinates the important research that needs to be done so that appropriate mitigation strategies can be developed. While the need for more research has been identified, a lot of information has already been accumulated and more is being acquired every year. Several key advances have been made to share this information among the members of the conservation and research communities.

Sharing the Science

The HCA (<http://hawaiiconservation.org>) is a coalition of 19 conservation organizations working together to protect and restore the natural resources of Hawai'i. A list of its institutional members (<http://hawaiiconservation.org/about/alliance_partners>) demonstrates the breadth and depth of cooperative commitment that has been made. Coordinated by the HCA, the Hawai'i Conservation Conference (HCC) is an annual three-day conference and is the largest conservation gathering in Hawai'i. Typically attended by ca. 1000 participants, the HCC has become an effective venue that facilitates sharing research results through forums, symposiums, workshops, lectures, and other media (<http://hawaiiconservation.org/activities/hawaii_conservation_conference>). An annual Nahelehele Dryland Forest Symposium is sponsored by Ka'ahahui O Ka Nahelehele (<http://drylandforest.org>), a Hawai'i island nonprofit organization. Its participating organizations and projects can be found at <http://drylandforest.org/partners>. In May 2011, SI and NTBG, with support from other organizations, co-sponsored a three-day scientific conference, "Evolution of Life on Pacific Islands and Reefs: Past, Present, and Future," in Honolulu. The conference proceedings are available at <http://botany.si.edu/events/2011_pacific>.

The Hawaiian Ecosystems At Risk (HEAR) website (<http://www.hear.org>) maintains a number of databases, image collections, and listservers that share technology, methods, and information in order to facilitate communication among decision-makers, resource managers, and the general public in support of effective science-based management of harmful non-native species in Hawai'i and the Pacific. HEAR also provides online discussion forums for a large number of conservation specialist groups, including all invasive species councils, environmental educators, and specialist groups on invasive plant pests and others (<http://www.hear.org/hearlists/index.html>).

The University of Hawai'i hosts a number of important conservation research facilities including the Center for Conservation Research and Training (<http://www.hawaii.edu/ccrt/CCRTOnline/Programs.html>). Other resources include the Hawai'i Seed Research facility at Lyon Arboretum, the Hawai'i Stream Research Center, and the Ecology, Evolution, and Conservation Biology Graduate Program. The University of Hawai'i Department of Botany also hosts the Hawaiian Plant DNA Library (<http://www.botany.hawaii.edu/faculty/morden/HPDL.htm>), the Pacific-Asia Biodiversity Transect (PIBITRA; <http://www.botany.Hawaii.edu/pabitra>), Weed Risk Assessments for Hawaii and Pacific Islands (<http://www.botany.hawaii.edu/faculty/daehler/wra/>), the HAW herbarium, as well as an Electronic Theses and Dissertations library (<http://www.herbarium.hawaii.edu/collections/etd/>).

Sharing Databases

In the last few years, cooperation between a number of agencies has allowed databases to "talk to each other" through shared data fields. This includes the Hawai'i State Rare Plant database, the U.S. Army Pohakuloa and Oahu databases, the Hawai'i Biodiversity Mapping Program, and the NTBG databases. To protect the locations of extremely rare plants, these databases are not available to the public online.

Sharing On-ground Restoration Techniques

The HCC, discussed earlier, is the primary venue where restoration practitioners share their experience, expertise, and new technologies with all levels of the conservation community (<http://hawaiiconservation.org/activities/hawaii_conservation_conference>). Additionally, the HRPRG is a network of practitioners from conservation agencies and organizations, both public and private, that shares information on recovery efforts on all the islands and communicates through meetings, an online listserver, and a web site (<http://www.hear.org/hrprg/index.html>). This web site includes a bibliography for restoration genetics, with guidance on collection and restoration protocols. The group was instrumental in the creation of the PEP and the mid-elevation, rare plant nurseries on several islands. The HRPRG has functioned to develop appropriate procedures and policies for dealing with rare and endangered plants and their recoveries (<http://www.hear.org/hrprg/index.html>).

Close Cooperation and Partnerships between Agencies/Organizations

The mutual sharing of staff, equipment, training opportunities, helicopter time, etc., among organizations in Hawai'i is frequent and essential for accomplishing our goals. Collaboration-coalition types of efforts are almost the rule, rather than the exception, in Hawai'i. We mention just two excellent examples of this. The Hawai'i Association of Watershed Partnerships (HAWP; <http://hawp.org>) comprises watershed partnerships on each island. This organization includes both private and public landowners, conservation groups, and citizen groups, all of whom work collaboratively toward landscape-scale conservation. Also, The Nature Conservancy of Hawai'i (TNC) works to preserve native landscapes and intact habitats for all of Hawai'i's living resources through a system of preserves and collaborations with landowners (<http://www.nature.org/ourinitiatives/regions/northamerica/unitedstates/Hawaii/index.htm>). TNC of Hawai'i offers state-of-the-art management tools, achieving substantial results that include the fencing of thousands of acres of native forests. This provides the long-term protection of rare species against the damage caused by feral ungulates. They work extensively with landowners and partners from both the public and private sectors.

Conclusions

While Hawai'i has been recognized for over 200 years as possessing a unique flora, it is only over the past several decades that the level of endangerment has begun to be quantified. Numerous organizations and many dedicated and passionate individuals have been working for years to document and conserve Hawai'i's globally important biodiversity. Although these efforts have yielded results, the continuing trend toward increased endangerment raises concerns locally and nationally. We believe that the GSPC's 2010 Objectives and Targets are an ideal framework for Hawai'i to coordinate and monitor the work currently being done and to bring much needed international awareness to our situation. Based on what other nations have done to create a national strategy for plant conservation, we propose that the HCA should develop an HSPC modeled after the GSPC. This will provide an effective template for our conservation work and tie directly into the global efforts under the United Nations Convention on Biological Diversity. Since the United Nations declared this the Decade of Biodiversity, there is no better time for Hawai'i to do this than now.

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